vents the instrument approaching too closely to the bed of the river, where it might be injured or retarded by obstacles. In the interior of the cylinder, C, there is a cylindric case, c_2 (Figs. 3, 4, and 5), in which a brass spring is fastened, and through which the pin, c_3, is carried. To this pin the end of the suspending rope, D, is fastened. The internal diameter of the cylinder, C, is a little larger than the outside diameter of the hollow rod, A, on which it is to slide. The part, c_2, to which the rope is attached, is connected with C by an arm which passes through a vertical slit in the hollow rod, A. Thus, the instrument is kept always, if the pipe, A, is properly placed, with its axis normal to the plane of the cross section. The cylinder, C, is also fitted with rollers, c_6 c_6, which render the motion on the fixed rod easy. After the instrument has been placed on the rod or staff, a bracket, E (Fig. 1), with a pulley, e_1, is attached at the top, and the rope is carried over this pulley. The rope, D, is wound on a barrel, F. This barrel is fixed with the frame, f_1, and the pin, f_2, on the arm, G (Figs. 1, 6, and 7), which is firmly fastened to the hollow rod, A. With the barrel is connected the apparatus, f_3, registering the depth at which the meter is at any moment. The fan, f_4, and gearing, f_5, regulate the rate of rotation of the barrel and permit the adjustment of the speed of the meter in its descent along the rod, A. By the handle, f_6, the meter is again raised. The lever, f_7, and ratchet

FIG. 6.

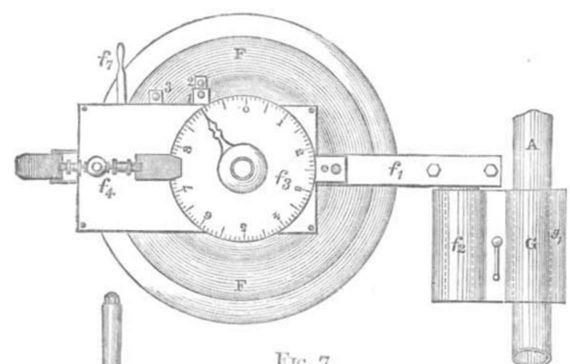
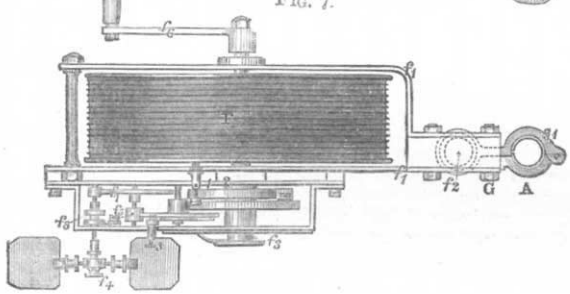


FIG. 7.



wheel, f_8 (Fig. 6), arrest the rotation of the barrel. The movement begins as soon as the ratchet is lifted by the lever. On the frame of the barrel, F, are fastened the contact screws, 1, 2, 3 (Figs. 1, 6 and 7), for attaching the wires of the electric circuit. The screw, 1, is connected with the rope, D, which is a copper-wire rope covered with insulating material. The rope is in electric contact with the shaft of the screw through the spring, c_3 (Fig. 5), because an insulated wire, c_7 (Figs. 5 and 3), connects the lower end of the pin, c_3, and the loop of one of the screws, b_7 (Figs. 2 and 3), which fasten the spring to the brass frame, b_2. The other conductor is the cast-iron pipe, A, which is in contact with the rest of the apparatus through the parts C, G, f_1, f_2 and F (Figs. 6 and 7). These parts are connected with the screw 2 (Figs. 1, 6, and 7). By putting a wire into the loop of screw 3 the depth of the meter below the water-line can be registered electrically. The registering apparatus, H (Fig. 1), has two dials, one marking single revolutions and the other hundreds of revolutions.

If desired, a recording arrangement can be added, the rotations of the meter being marked on a slip of paper in the same way as in a writing telegraph or chronograph. Prof. Harlacher used this arrangement in determining the variation of velocity at a given fixed point. The battery, I, and the clock, or indicator, H, with the rod, A, carrying the meter, are placed on a float, P. The sight vane, K, is fastened to the rod, A, so that it is parallel to the plane of the cross section, and then the axis of the screw is normal to the cross section and parallel to the current. The float is anchored in large rivers and fastened to guide ropes or poles in smaller streams. As soon as the work at one vertical of the cross section is finished, the anchor ropes on one side are slackened and on the other tightened, so as to bring the float into a new position in an easy and a speedy manner. The float must be built so as to be capable of supporting four or five persons.

The determination of the mean velocity at one vertical, by allowing the meter to slide once from the surface of the stream to the bottom, is accomplished thus. The meter, B, and all its connections, C, c_1, &c., are brought to within a few inches of the water surface, the fingers of the electric clock being set to zero. Then the barrel, F, is released by the lever, f_7, Fig. 6. As soon as the axis of the screw touches the water surface a signal is given, the electric clock is brought into the circuit by a spring lever, and begins to count the rotations of the screw. It is necessary to commence with the meter some small distance above the water surface, in order that it may acquire the proper descending velocity previous to the counting of the rotations. In a certain number of seconds the meter descends from M to N (Fig. 1), having at each point in its descent acquired the velocity of rotation corresponding to the velocity of the water at that depth. Dividing the number of revolutions by the number of seconds the rate of rotation corresponding to the mean velocity at that vertical is found. The fact that the disk, c_1 (Figs. 1, 2, and 3), prevents the meter from descending exactly to the bottom entails a small correction. This correction, however, will be more insignificant the larger the difference of the heights M N and N O, that is, the deeper the river in which the observations are made. It is a matter of course that the readings of the instrument at each vertical should be repeated, and the average of the results taken for the true mean velocity. The results of single measurements will not differ much from each other, but the repetition of the reading will give a certainty that all the variations of the velocity at the given vertical are allowed for.

Before using the meter, its constants must be determined in the same manner as with the Woltmann apparatus. A length is marked out in a still-water basin, and the meter is frequently moved through this distance at different speeds. It is essential that the movement of the boat or float on which the meter is fixed should be a uniform one.

The above description of the apparatus will prove that the advantages of this form of meter are of considerable importance.

THE STORAGE OF ENERGY[1]

THE subject of this lecture has been called by the world at large, even by well-informed *Punch*, "The Storage of Force." Why, then, have I ventured, in my title, to differ from so popular an authority? For this simple reason—that you cannot store force any more than you can store time. There is as much difference between force and work, as there is between a mile and the speed of a train or between a ship and a voyage. Work involves two distinct ideas combined, whereas force only involves one. When a weight rests on the ground, the weight pushes the ground down with a certain force, and the ground pushes the weight up with the same force. If, then, there were such a thing as a storage of force, the mere resting of a weight on the ground would be such a storage, since the force exerted between the weight and the ground never grows less. But, I need hardly say, it would be beyond the ability of the cleverest engineer to work a machine, or drive a train, by using a weight resting on the ground; the very expression, "dead weight," shows how useless it is for the practical purposes of producing motion. A weight resting on the safety-valve of a steam-engine may be a very good means of adjusting the pressure at which the valve shall open and liberate the excess steam, but this weight will never work the engine.

Work is force exerted through space; if a weight P be raised through F feet, P × F foot-pounds of work will be done, and there will be a store of P × F foot-pounds of work in the raised weight.

The continuous evaporation of the water from the seas and

[1] Abstract of a lecture delivered at the London Institution on Thursday, March 2, by Prof. W. E. Ayrton, F.R.S.

rivers by the heat of the sun, and its subsequent deposit in the form of rain on the hill-tops, supplies us with another very large raised weight store of energy, and which is practically utilised when the water falling down the hill-side works out water-wheels and turbines.

Various stores of energy arise from the separation of two bodies which desire to come together. The vast fields of coal form an enormous store of energy, owing to the tendency of carbon to combine with oxygen. Copper which is found pure and zinc, when separated from the oxygen with which it is combined in nature, are examples of the same kind. We may also have a store of energy arising from two bodies being too close together, and which desire to move apart; as, for example, in a coiled spring, in compressed gas, in two similar magnetic poles, or in two similarly electrified bodies near together.

The experiments now shown are examples of energy previously stored being utilised. This grindstone is being turned by a falling weight, the ventilating fan by falling water, this saw is worked by the gas-engine, the lathe by this galvanic battery, and the sewing machine by three Faure accumulators.

The water which is falling from the top of the building, and which is working this turbine, was really stored in the cistern for drinking and washing purposes, and, although serving us as a store of energy, it was not pumped up for this purpose. Indeed the price charged for water by the water companies would prohibit its use for the production of power. For, with water at a pressure of 100 feet, and at as low a price as *6d.* per 1000 gallons, it would cost *1s. 4d.* per horse-power per hour if the turbine had 80 per cent. efficiency.

In addition to the natural stores of water-energy on our hill-tops, there are also artificial stores of water-energy, or Armstrong's water accumulators, as they are called, although invented long before Sir William Armstrong's time, and which are employed in many large steel works, docks, &c. Water is periodically pumped into a cylinder with a heavily-weighted piston, which is therefore raised when the water is pumped in. If then at any moment, at any part of the works power is required, a tap is opened, and this large weight falling at the reservoir cylinder, drives out the water and performs the desired piece of work.

Now I want to consider how far it would be possible to drive a tramcar by one or other of these various sources of power. An ordinary tramcar for forty-six passengers weighs $2\frac{1}{2}$ tons, and when full of people about $4\frac{1}{2}$ tons. To pull such a car at the rate of six miles an hour along an ordinary line requires about $1\frac{1}{2}$ horse-power. To produce such an amount of power for one hour requires an expenditure of over 2,800,000 foot lbs. of work, or if produced by a weight falling say through 10 feet, would require the weight to be over 100 tons.

Armstrong's water accumulators are therefore clearly useless for the purpose, and coiled springs are too cumbersome.

Steam-engines are occasionally employed on tram-lines, and from the point of economy are much superior to horses; but there is the great disadvantage of the smoke, noise, and the terror of the horses of other vehicles. A detached tramway engine weighs as much as a full car, consequently nearly half the total horse-power employed is used in propelling the engine and boiler, and there is also the waste of power caused by the rapid radiation of heat from the boiler of a small engine. Gas-engines, though saving the weight of the boiler and coal, have the compensating disadvantage that per horse-power, the weight of a gas-engine is so much greater than that of a steam-engine, and cannot therefore at present be economically employed for tram-cars.

Compressed air engines have been employed with considerable success by Col. Beaumont for driving tramcars, and he has succeeded in storing in one cubic foot of air at 1000 lbs. pressure per square inch enough energy to pull three tons about half a mile along an ordinary tramway. But successful as this system is from the point of economy, there is the same objection that there is to the steam tram, viz. the comparative great weight of the locomotive. The detached compressed air engine weighs about 7 tons, while the car full of passengers is hardly 5 tons, so that seven-twelfths of the total horse-power expended is employed in pulling the compressed air engine alone. I understand it is proposed to build combined cars and compressed air engines, a change that will probably lead to a great improvement.

In order to obtain mechanical motion, we require a store of energy, and some machine for converting the energy stored into mechanical work. Now experiment shows that the weight of an electric motor is but a small fraction of the weight of a small steam-engine and boiler per horse-power developed. Electric motors, indeed, can be easily made to give out work at the rate of 1 horse-power per 50 lbs. dead weight of machine, and hence the great advantage of using them for movable machinery. [Experiment shown of drilling holes in thick wood with a hand electro-motor and raising large boxes with a small electric hoist.] The most economical store of energy we can convert into mechanical energy by the agency of electricity is evidently the energy of coal, and this is the store we shall mainly employ in driving electric motors. That is to say, coal will be burnt to produce mechanical motion, the mechanical motion will work a magneto or dynamo electric machine to produce an electric current, the electric current will be conveyed along the wires, and at the other end, by means of an electro-motor, the electric current will be reconverted into mechanical work. [Experiment shown.]

Instead of converting the electric current energy into mechanical motion I can convert it into heat, and I shall then have, as you see, the ordinary electric light.

But if the engine breaks down, the electric motor at the other end must stop, or the electric light go out; the constant occurrence of which accident has just decided the authorities at the Manchester Railway Station to discontinue the use of the electric light. To prevent this effect following such an accident, an electric accumulator is needed, that is a reservoir which has been drinking in the electric energy when the engine was going at its best, and which will now give it out when the engine has stopped. Again, apart from accidental fluctuations in the speed of the engine, or total breakings down there is another most important use for the electric accumulators. That the electric lighting of towns will become general, I need hardly stop to prove to you, and that it will be carried out in ways quite different from the expedients temporarily adopted is also equally obvious. But users of electricity in this country have at present to manufacture their electricity as they require it, and are in the same position that gas-companies would be in if they were unable to store their gas, but had to manufacture it all while it was being consumed. They would evidently require much larger and consequently more expensive plant. Now the experience of two years has shown that, for large buildings, the electric light is far cheaper than gas. How much cheaper will it then become, when the electric energy can be manufactured at any time convenient, and stored until it is required to be used.

The earliest form of accumulator was simply a voltameter worked backwards. Now although Sir William Grove greatly increased the efficiency of this secondary battery by coating the plates with platinum black, still it was of little practical importance because of the rapid escape of the greater portion of the gases formed, if the charging was continued for a long time, as well as their diffusion through the liquid.

It is clear, then, we must arrange matters so that the passage of the primary current, forms on each plate a substance which has no tendency to wander over to the other. Such a substance must obviously be a solid, and a solid not soluble in the liquid. Now, an oxide of lead satisfies, in a marked degree, these conditions, and hence the employment in secondary batteries of this oxide, produced usually by sending an electric current between the lead plates immersed in dilute sulphuric acid.

But, in addition to having the plates near together, they must have large surface, in order to store much electric energy. And the way to give the plate a large surface, without making it inconveniently large, is to make it spongy. Hence what is aimed at is two spongy lead-plates near together.

Planté's method of accomplishing this occupied some months, and even when "well formed," his cell does not store very much electric energy, so that it has hardly ever been used for any commercial purpose.

In 1880, M. Faure thought of the device of putting a thick layer of red lead on his lead plates, a substance which can easily be reduced to spongy lead by the passage of a current. The plates, after being coated with red lead, are then wrapped in flannel jackets and put side by side in a box, every alternate plate being connected together, so as to practically produce two plates with very large surface very near together. To form the cells, reverse currents are sent somewhat in the same way that they are sent in forming the Planté cell, with the exception that only days and not months are required in the formation. The red lead on the one side is reduced to a spongy material, which is probably lead very slightly oxidised; on the other side, it is reduced to lead peroxide. Charging the cell, by sending a current in the direction of the last current sent, reduces the sub-

oxide to pure lead, and the lead peroxide, on the other side, to an even more oxidised salt. On using the cell to produce an external useful current, the pure spongy lead becomes again slightly more oxidised, and the peroxide slightly less oxidised. In fact, there is a small quantity of oxygen which travels backwards and forwards as the cell is charged and discharged.

Now, does such a cell store electricity? No! emphatically no! When charging it, just as much electricity passes out as passes in, and, when discharging it, just as much electricity passes in as passes out.

Imagine a stream of water was turning a water-wheel, and the water-wheel was employed to raise corn up into a granary, the arrangement might be called one for storing corn, but certainly not one for storing water. So a secondary battery does not store electricity, but electric energy.

The pith, then, of Faure's discovery is the mechanical placing of a salt of lead on the leaden plates the presence of which layer of lead salt enables spongy lead to be produced in a few days, instead of requiring many months, when the spongy lead is electrically formed out of the lead plates themselves by the long passage of electric currents.

The next point to consider is: (1) the storing capacity of such an accumulator; (2) its efficiency; (3) its durability. Now I am, I am glad to say, able to give you more than hearsay evidence on this point, since Prof. Perry and myself have been engaged on rather a long series of experiments on this subject. I may mention that we were both rather sceptical about the merits of the Faure accumulator before commencing this investigation, since we feared that the reports of its excellent action were almost too good to be true. Our doubts, however, gradually dispelled themselves as the investigation proceeded, and we now are able to add our tribute to its practical value.

Let us take a single example of the storing capacity. A certain cell, containing 81 lbs. of lead and red lead, was charged and then discharged, the discharge lasting eighteen hours—six hours on three successive days; and it was found that the total discharge represented an amount of electric energy exceeding 1,440,000 foot lbs. of work. This is equivalent to 1 horse-power for three-quarters of an hour, or 18,000 foot lbs. of work stored per lb. weight of lead and red lead. The large curve shows graphically the results of the discharge. Horizontal distances represent time in minutes, and vertical distances foot lbs. per minute of energy given out by the cell, and the area of the curve therefore the total work given out. On the second day we made it give out energy more rapidly than the first, and on the third more rapidly than on the second, this being done of course by diminishing the total resistance in circuit. During the last day we were discharging with a current of about 25 ampères. But in connection with the storing power, there is a very curious phenomenon to which I think not nearly sufficient attention has been directed, and that is the resuscitating power of a Faure's cell. When a cell has been apparently completely discharged, and is left for a few hours by itself, it appears to have obtained a new charge. For example after the eighteen hours discharge just referred to, although there apparently was no electric energy left in the cell at the end, it was found that after a few hours' insulation, the accumulator could give a current of over 50 ampères, and produce therefore bright flashes of fire. The phenomenon is wonderfully like the invigorating action of sleep. In one case, during our experiments of an extremely rapid and powerful discharge, we found that in subsequent discharges after rest, the cell gave out three times as much energy as it did in the first discharge. The neglect of considering this resuscitating power has doubtless misled many people who have possibly discharged a Faure's cell very rapidly, into under-estimating its storing capacity.

Secondly, as regards efficiency. The efficiency of an electric accumulator—that is, the ratio of the work put into it to the work given out—depends on the speed with which it is charged, and the speed with which it is discharged. If charged or discharged too quickly, a certain amount of energy will be wasted, heating the cell itself; since, whenever a current passes through a body, some heat is developed, and the greater the current, the greater the heat, the latter, indeed, increasing much more rapidly than the current. Now, it is possible, in a way I will not at the moment trouble you by explaining, to distinguish between the work given to the cell to produce chemical decomposition and the work wasted by too hurried charging. Similarly, in discharging, it is also possible to find out how much of the electric energy stored up in the cell is wasted in heating it by too hurried discharging. Allowing for such unnecessary waste, experiment shows that, for a million foot-pounds of stored energy discharged with a mean current of 17 ampères, the loss in charging and discharging combined need not exceed 18 per cent.; indeed, in some cases, for very slow discharges, we have found it not to exceed 10 per cent. I do not, of course, mean by this, as some people have mistakenly imagined from the published numbers of Prof. Perry and myself, that a current of only 17 ampères can be obtained by discharging a single cell; since, of course, far greater discharge-currents can be produced if the external resistance be low; indeed, I shall show you a constant discharge of about 70 ampères presently. In speaking of the number 17, I merely mean to say that was the average current when the experiments on the efficiency above referred to were made.

As to deterioration, two months constant charging and discharging of the two test-cells showed no signs of deterioration.

I have said that a cell containing 81 lbs. of lead and red lead stored 1,440,000 foot-pounds of work. Now, consider what that means. It represents all the energy required to be expended to pull a tramcar containing forty-six passengers over two miles, after allowing for considerable waste of power in the electrical arrangements. The electromotor and gearing need not weigh, as I told you, more than about 200 lbs., to produce about two horse-power. We have, therefore, this wonderful conclusion, that about 300 lbs. dead weight contains all the energy and all the machinery necessary for over two miles' run of a tramcar with forty-six passengers. Now, is this result actually obtained at present in the tramcar running at Leytonstone, and which is propelled by Faure's accumulators? No, and why? Partly because the electro-motor has not been made to suit the accumulators, nor the accumulators the electro-motor, nor is the gearing adapted to either.

The cells, as at present made, would not give off their energy quickly enough; hence a greater number are employed, but which, consequently, require to be charged much less frequently than would otherwise be necessary. Indeed, in a ton of the cells as at present constructed, there is about fifty miles' run of a tramcar containing forty-six passengers.

But, in spite of the temporary character of this arrangement, the total weight of the Faure cells, dynamo and gearing combined, used at Leytonstone, is only 1½ tons, or one-third of the weight of a detached steam or compressed air-engine commonly used for tramcars.

Spacious as is the Lecture Theatre of the London Institution, it is unfortunately not large enough to admit a tramcar. I have therefore done the next best thing to prove to you that the Faure accumulators really contain a vast store of available energy. We have here a circular saw which is now cutting wood over an inch in thickness. As you see, the circular saw is driven by that Gramme electro-motor, and the electro-motor itself is fed by the energy stored up in these accumulators, and which was put into them by a dynamo machine yesterday, on the other side of London.

When the Faure's accumulator was first invented, there were various suggestions of electricity being delivered at houses every morning like milk in cans, and the exaggeration of this idea no doubt did something to prejudice the cells in the eyes of the public. The reason why milk is delivered in cans and brought by carts is simply because the total quantity required is so extremely small. If milk were required to be consumed in large quantities like water is, we should have it sent through pipes, and not by cans. The main use of the accumulators will be as stationary reservoirs corresponding with cisterns for water or gasometers for gas. But in certain cases where the accumulators can be used to propel a cart, as in the case of tramcars, not the cart employed solely to carry the accumulators, then there is not the same objection to their being moved about, seeing that the total weight necessary is small compared with that necessary for a steam-engine or a compressed-air engine for tram lines to develop the same horse-power.

Again, just as ordinary electro-motors are not made to discharge a Faure's cell rapidly, so ordinary electric lamps are unsuited for this purpose; and, therefore, although there is enough energy, in a 100 lbs. dead weight of Faure accumulator, to give a light of 1500 candles for thirty minutes, an ordinary electric lamp cannot be illuminated at all by a single cell. Mr. Edison, however, has been turning his attention to this subject, and here is the result of his handiwork, which arrived last night from America, and which is, therefore, shown for the first time in England this evening. This incandescent lamp, as you see,

only requires four Faure accumulators to illuminate it, this one eight, and this other one twelve. But must the accumulators be even as large as those I am using on the table? The answer is, No; if you do not require them to give out the light for a very long time. Four much smaller boxes would give just as much light as you see at the present moment; but, of course, would not keep the light burning so long. It is, therefore, now possible to have a box of accumulators and an incandescent lamp, and the whole thing quite easily carried by one man.

Last year Prof. Perry drew attention, in his lecture at the Society of Arts on the "Future of Electrical Appliances," to the great waste of energy that is produced by the coal being carried to the steam-engine, instead of steam-engines being brought to the coal, and the power given out by the engines conveyed electrically to the place where it was commercially required. Why, said he, should not the coal be burnt at the pit's mouth, or in the pit, or even in that part of the mine where the seams were thickest, and the engines driven by burning it used to work large dynamo-machines on the spot, and the power transmitted electrically to any towns where it was required? Again, it has been often asked, why should not the wasted power in streams be utilised? At present it is more economical to use steam-engines in a town than to do work in the country by means of the streams, and convey the manufactured articles over the hills into the towns; and for that reason one sees the old water-wheels, in the neighbourhood of a place like Sheffield, being gradually deserted, and the men preferring to pay a higher rent for steam-driven grindstones in the town, to a smaller rent for water-driven grindstones in the suburbs. The question then arises would it be possible to convey economically the power from the coal-pits or from the streams into the towns by means of electricity; and this obviously turns on, how much power can be got out of one end of a wire compared with the amount that is put in at the other. I have, during this evening, been talking of the measurements of electric energy put into or taken out of an accumulator in foot-pounds, and you may have wondered how it was possible to measure electric energy in the engineer's unit of foot-pounds. In reality it is very simple. The maximum amount of work a waterfall can do, depends on two things, the current of water and the height of the fall. In the same way, the work a galvanic cell or accumulator can do, depends on two things, the current it is producing, and what is called its electromotive force, the latter being analogous with the difference of pressure or head of water. Again, when electric energy is being turned into mechanical work by means of an electro-motor, the energy which is being put into the motor can be measured by the product of the current sent through the motor, and the electromotive force maintained between the terminals of the motor. Now, here are two instruments, devised by Prof. Perry and myself, an Am-meter and a Volt-meter, the one for measuring a strong current, and the other a large electromotive force. With these we will now make simultaneous measurements when we allow this motor, which is driving the lathe, and which is itself driven by an electric current, to run at different speeds. First, we will start with the motor, which has one ohm resistance absolutely at rest, by putting a break on it, and ending by allowing it to run as fast as possible.

Experiment performed and the following results were obtained:—

Speed of motor.	Current in Ampères.	Electro-motive force between terminals of the motor in volts.	Electric power put into the motor in foot pounds per minute.	Power wasted by the current heating the wires of the motor in foot pounds per minute.
0	15	15	$15 \times 15 \times 44.25$ *i.e.* 9956.25	$15^2 \times 1 \times 44.25$ *i.e.* 9956.25
Slow	10	21	$10 \times 21 \times 44.25$ *i.e.* 9292.5	$10^2 \times 1 \times 44.25$ *i.e.* 4425
Fast	4	28	$4 \times 28 \times 44.25$ *i.e.* 4956	$4^2 \times 1 \times 44.25$ *i.e.* 708

We see in the last case, when the load was light and the speed of the motor very great, there was less than one-tenth of the waste of power arising from the current heating the wires when the speed was very slow. On the other hand, we observe that the electro-motive force between the terminals of the motor has been practically doubled.

This simple experiment really points to the solution of economic transmission of power by electricity, and to which Prof. Perry and myself have on numerous occasions directed attention. It is, to allow only a very small current to pass through the wires connecting the electro-motor with the generator, and to maintain a very great electro-motive force between them; since, in this way, the amount of power transmitted can be made as large as we like, and the waste from the heating of the wires from the passage of the current as small as we like.

Reasoning in this way, Sir W. Thomson showed, in his inaugural address last year to the British Association, that, if we desire to transmit 26,250 horse-power by a copper wire half an inch in diameter, from Niagara to New York, which is about 300 miles distance, and if we desire not to lose more than one-fifth of the whole amount of work—that is, to deliver up in New York 21,000 horse-power—the electromotive force between the two wires must be 80,000 volts. Now, what are we to do with this enormous electromotive force at the New York end of the wires? Fancy a servant dusting a wire having this enormous electromotive force. You might as well, as far as her peace of mind is concerned, ask her to put a lightning flash tidy.

The solution of this problem was also given by Sir W. Thomson on the same occasion, and it consists in using large numbers of accumulators. All that is necessary to do in order to subdivide this enormous electromotive into what may be called small commercial electromotive forces is to keep a Faure battery of 40,000 cells always charged direct from the main current, and apply a methodical system of removing sets of 50 and placing them on the town supply circuits, while other sets of 50 are being regularly introduced into the main circuit that is being charged. Of course this removal does not mean bodily removal of the cells, but merely disconnecting the wires. It is probable that this employment of secondary batteries will be of great importance since it overcomes the last difficulty in the economical electrical transmission of power over long distances.

I will conclude my lecture by illustrating one of the other important uses to which the accumulator can be applied, and that is the practical lighting of railway trains, which may be seen in daily operation in the Pullman cars on the Brighton line. The most natural method of lighting a railway train would be to attach a dynamo-machine to the axle of one of the carriages—the guard's van, for example—and the rotation of which, necessarily very rapid when the train is going fast, would, without the use of any gearing, produce the necessary current. But the difficulty that immediately meets us is that as soon as the train slows, or stops at a station, or in consequence of the signal being against it, the speed of the dynamo-machine will diminish and the lights will go out. If, however, while the train is going fast, the dynamo performs two operations, the one to keep the lights burning, the other to charge a battery of Faure's accumulators on the train, then the electric energy so stored can be applied to maintain the lights while the train is going slowly or stopping. With such an arrangement there would be, of course, an automatic contrivance for disconnecting the dynamo-machine from the circuit when the speed becomes too low; otherwise the Faure's accumulators would simply discharge themselves back through the dynamo-machine.

Imagine, now, we are in a train which is going slowly, or which has actually stopped, and that the Faure accumulators lying here on the floor is the Faure battery in the train, and which have been charged when the train was going fast; then that it has sufficient store of energy to continue lighting is proved, because, on connecting these two wires, those fifty Maxim lamps, kindly lent me by the Electric Light and Power Company, and eight Edison lamps before you, are instantly brilliantly illuminated, each of the former possessing about forty candle-power, and each of the latter about seventeen, and giving, therefore, far more light than is, at present, ever supplied to a whole train of twelve carriages. The light, you observe, is perfectly steady, and is turned on and off at will. Imagine, now, we are in a tunnel in the daytime, and the lights, therefore, burning. We now emerge from the tunnel into daylight. I disconnect the wires, and the lights are instantly extinguished. Again, it may be we are entering a second tunnel. The wires are again connected by the guard, and we have the whole of this lecture-theatre, which represents the train, brilliantly illuminated.

There has been an erroneous impression existing lately, that the Faure accumulator could not produce a constant current of more than 17 Ampères; but, that this is a mistake, is clearly seen from the fact that, at the present moment, each of the cells in this room is producing a current of about 75 Ampères.

Electric storage of energy, therefore, makes us nearly independent of accidents to the engine or dynamo machine, or irregularities in their working, enables us to receive our supply of electric energy from the central supply station in our proper turn, and independently of the particular time we require to utilise it, and lastly it enables large amounts of power to be transmitted over very long distances with but little waste.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE

OXFORD.—The following notices have been issued with regard to lectures and classes in Natural Science for the summer term, beginning April 11:—

Prof. Clifton will give a course of demonstrations on instruments and methods of observation employed in optical measurements. The course is intended as an introduction to the study of practical physics in the Clarendon Laboratory. Mr. Stocker will deliver a course of lectures on Elementary Hydro-mechanics, and Mr. Heaton will form a class for the study of problems in Elementary Statics and Hydrostatics, these two courses being designed to meet the requirements of candidates for the Preliminary Honour examination in Natural Science.

Prof. Moseley, the new Linacre Professor of Physiology, proposes to commence a course of Comparative Anatomy, to extend over one year. The Professor's course is open to all students who have attended a course on Practical Biology, or Mr. Robertson's course on Histology. The Professor will attend after his lecture each day until 1 p.m. to superintend the practical work, which will be continued in the afternoon of that day and on the following day, by all students able to attend. Mr. Charles Robertson will give a course on the use of the Microscope and Histology to a junior class. The Professor will give an inaugural lecture on "The Zoological Results of the *Challenger* Expedition," in the large lecture-room at the University Museum, at 8.30 p.m. on Thursday, April 20. The lecture will be illustrated by means of photographs exhibited with the lime-light.

In the Department of Geology Prof. Prestwich proposes to have excursions to visit the several geological sections in the neighbourhood of Oxford on several Saturdays during the Term; and will lecture or give informal instruction on the subject of the excursion on each preceding Friday. Notice will be given from time to time in the *Gazette* and in the Museum of the places to be visited, hours of meeting, &c.

The Biological Fellowship at University College has been awarded, after examination, to Mr. J. T. Cunningham, B.A., late Brakenbury Natural Science Scholar at Balliol College.

Mr. Cunningham obtained a 1st Class in Mathematical Moderations, and a 1st Class in the Final Honour School of Natural Science.

The Delegates for licensing lodging-houses have appointed Mr. E. F. G. Griffith, C.E., to be Sanitary officer of the Delegacy for a period of two years.

Examinations for the Degree of Batchelor of Medicine, both First and Second, will be held in Trinity Term, on days to be hereafter notified.

Candidates for either of these examinations are requested to send their names, on or before May 1, to the Regius Professor of Medicine, Medical Department, Museum.

CAMBRIDGE.—Under the action of the new Statute A, which comes into force from the end of the present term, the entire Cambridge year is compulsorily lengthened a fortnight, and may be further lengthened at the pleasure of the Senate. Three terms are to be kept between October 1 aud June 24 of the succeeding year, to include 227 days. Residence must be for not less than three-fourths of each term, instead of two-thirds as heretofore.

Section 12 of the Second Chapter of the Statute is important in the interests of science and reads thus:—"Students in science who, having already taken a degree in Arts, Law, Medicine, or Surgery, have given proofs of distinction in science by some original contribution to the advancement of science, and have done all that is required by the statutes and ordinances of the University, may be admitted to the title of Doctor Designate in Science, and shall afterwards be created doctors at the time prescribed by the University." In this Statute the claims of original work are fully recognised, and there is only necessary the formulation and promulgation of adequate regulations to place science in a sufficient position of honour in the University. It is provided in a subsequent chapter that honorary degrees in science may be conferred on foreigners or British subjects of conspicuous merit.

Section 19 of the same chapter is important, for it sanctions the adoption of affiliated colleges in any part of the British dominion, the recognition of their lectures and arrangements, and the allowing of periods of study at them not less than two years, as counting three terms towards a Cambridge degree.

The last report of the Board of Examinations (Ordinary Degrees) shows that in the year 1881 there were forty-eight candidates in chemistry, of whom nine attained a first class, and their papers were very favourably reported on, while fourteen failed; the examiner in geology (in which there were only three candidates) recommends that the examination should include one paper devoted to practical work, and that the subject should be divided into two branches, petrology and palæontology, of which one only need be taken. This seems an undesirable separation, seeing that the degree is given for geology only. In botany there were six candidates, of whom three passed in the first class, and three failed. Zoology attracted only two candidates. These results do not show that these latter subjects are neglected, but that a considerable proportion of the candidates who do not take honours, including many medical students, find chemistry the most advantageous subject for the B.A. degree.

The Examiners in Mechanism and Applied Sciences report favourably of the work done; there were five candidates in mechanism, two in electricity, and none in theory of structures. The papers were well done, and showed real interest in the subject, as well as a thorough appreciation of the principles.

SOCIETIES AND ACADEMIES

LONDON

Zoological Society, March 7.—Prof. W. H. Flower, F.R.S., president, in the chair.—The Secretary exhibited and made remarks on some living examples of *Helix hæmastoma* from Ceylon, which had been forwarded to the Society by Mr. J. Wood-Mason, F.Z.S.—Mr. W. A. Forbes read a paper on certain points in the anatomy of the Great Anteater (*Myrmecophaga jubata*), as observed in two adult female specimens that had lately died in the Society's Gardens. The arrangement of the ducts of the submaxillary glands and their relations to the stylo-hyoid muscle, the composition of the anterior cornu of the hyoid bone, the presence of clavicles, and the structure of the brain and of the female reproductive organs, were amongst the chief features touched upon.—Capt. G. E. Shelley read an account of the birds collected by Mr. Joseph Thomson while engaged on an exploration of the river Rovuma, East Africa. The collection contained examples of forty-three species of birds, among them being two new species, proposed to be called *Merops dresseri* and *Erythrocerus Thomsoni*.—A second paper by Capt. Shelley gave an account of a series of birds recently collected by Sir John Kirk, in Eastern Africa. This collection was made chiefly in the neighbourhood of Mambois, on the eastern slopes of the mountain-range which separates Ugogo from the Zanzibar province.

Anthropological Institute, March 7.—Major-General Pitt-Rivers, F.R.S., president, in the chair.—Mr. E. F. Newton, F.G.S., exhibited a Romano-British burial urn containing human bones that was found in Cheapside, about 18 feet below the footpath, in 1879. Two of the bones have green glass melted around them.—Mr. E. H. Man read the first part of a monograph on the Aboriginal inhabitants of the Andaman Islands. The paper contained an exhaustive description of the natives, based upon the lines laid down in the "Anthropological Notes and Queries of the British Association." Many points regarding the physical characteristics of these savages, on which misapprehensions have hitherto existed, were noticed. The latter portion of the paper was devoted to a description of the tribal communities and the peculiarities connected with the sub-division of the same among inland and coast-men; and reference was made to the system of rule and the power of the chiefs, and various details connected with their customs and mode of life were dealt